CHAPTER 1

What Is Meaningful Learning?

WHAT IS LEARNING?

The first word of the title of this book is learning. Why? Because we believe that learning should be the most important outcome of schools. Learning is what humans do best, and school is supposed to foster learning. Why are humans such effective learners? Biologists, psychologists, anthropologists, and others generally agree that it has a lot to do with our relatively large brain size. So, we begin this book by briefly examining the question of what it means to learn.

There are many conceptions of learning. Based on their experiences and beliefs, people have constructed different theories about what it means to learn. These theories and their assumptions about learning and its outcomes differ. You may be tempted to ask, "Well, which one is right?" We can only tell you that they are all somewhat right. They are theories, that is, explanations by theorists about how they think the world works. Theories are too often taught as objects of truth. But everyone, from toddlers through experts, naturally constructs theories about how the world works. Some theories are just better informed. The following theories attempt to explain learning phenomena. However, no theory can explain all learning phenomena.

Learning Is Biochemical Activity in the Brain At the most material level, learning requires the release of a neurotransmitter from the hippocampus that facilitates the transmission of minute electrical pulses between the neurons of the brain. Patterns of behavior and cognitive activity are associated with patterns of neuronal firing. So learning is a matter of engramming certain patterns of neu-ronal connections. CAT scans and electroencephalographs (machines that monitor brain activity) can show learning occurring, as different areas of the brain light up when people are engaged in different learning tasks. Like most people, the philosopher Descartes wasn't satisfied with this conception of learning, so he distinguished between the body and the mind. The mind, and the learning it affords, is more than the body. Most people agree that human learning depends on brain activity but cannot be adequately described in terms of it.

Learning Is a Relatively Permanent Change in Behavior Behavioral psychologists of the late 19th and early 20th centuries believed that learning is evidenced by behavioral dispositions. When exposed to certain stimuli, people respond in predictable ways if they are reinforced for their performance. Even complex behaviors, such as language learning, can be described as behavioral tendencies. Behavioral psychologists focused their research on describing laws of human behavior. Cognitive psychologists believed that the human mind possessed intentionality and originality and so was more than a collection of reinforced behaviors. However, behaviorism very accurately describes many aspects of social learning. Most of us would not work without a paycheck. And behavioral methods work quite effectively with many special learning populations. All people respond to reinforcers on some level.

Learning Is Information Processing The early cognitive psychologists and systems thinkers conceived of human learning as information processing. Like computers, humans take in information, then hold it briefly in short-term memory until they can find a place to store it permanently in long-term memory. When faced with a task, we retrieve information from long-term memory and shift it into working memory where we can use the information to perform some task. Learning is a matter of developing more sophisticated processing methods. Although information processing theory identified some of the mechanisms of mind, contemporary constructivist philosophers (described later in this chapter) believe that the human mind is uniquely capable of making meaning from its environment, a process that cannot adequately be explained using machine metaphors.

Learning Is Remembering and Recalling The emphasis on information processing legitimized perhaps the oldest conception of learning, what you know. Almost all formal educational institutions have always measured knowledge in terms of what students are able to remember when given an examination. Learning is a process of "knowledge acquisition," a filling-up of the mind. If you are highlighting any of this text in preparation for an examination, then your teacher (and you, tacitly) believes that learning is remembering. However, constructivist philosophers believe that knowledge is more than remembering, that we strive to make sense out of what we are studying.

Learning Is Social Negotiation Meaning making is seldom accomplished individually. Rather, humans naturally tend to share their meaning with others, so meaning making more likely results from conversations than cramming. Just as the physical world is shared by all of us, so is some of the meaning that we make from it. Humans are social creatures who rely on feedback from fellow humans to determine their own identity and the viability of their personal beliefs. Social con-structivists believe that meaning making is a process of negotiation among the participants through dialogues or conversations. Learning is inherently a social-dialogical process (Duffy & Cunningham, 1996). People with similar experiences enjoy discussing those experiences, so they can learn from each other.

Learning Is Thinking Skills Many theorists believe that learning is best exhibited through guile and wit, the ability to think more cleverly than others. Critical thinking as an issue emerged during the 1970s and 1980s as an antidote to reproductive, lower-order learning (Paul, 1992). There are many models of critical thinking, but most emphasize *logical* thinking (judging the relationships between meanings of words and statements), *critical* thinking (knowing the criteria for judging statements covered by the logical dimension), and *pragmatic* thinking (considering the background or purpose of the judgment and the decision as to whether the statement is good enough for the purpose) (Ennis, 1989). Learning requires showing that you can analyze and apply knowledge, according to critical theorists.

Learning Is Knowledge Construction Individuals make sense of their world and all that they come in contact with by constructing their own representations or models of their experiences. Knowledge construction is a natural process. Whenever humans encounter something they do not know but need to understand, their natural inclination is to attempt to reconcile it with what they already know in order to determine what it means. Toddlers are constructivist machines. They constantly explore their worlds and frequently encounter phenomena that they do not understand. So they continue to explore it, familiarizing themselves with its possible functions and limitations. Parents try to intervene by teaching them lessons, but toddlers prefer to explore and learn for themselves.

Learning Is Conceptual Change Many conceptual change theorists believe that learning is a process of making sense out of domain concepts in such a way that they develop coherent conceptual structures. In order to make meaning, humans naturally organize and reorganize their naive models of the world in light of new experiences. The more coherent their theories of the world, the better are their conceptual structures. More contemporary conceptual change theorists (Schnotz, Vosniadou, & Carretero, 1999) emphasize the role of context in conceptual reorganization. Conceptual change, according to them, is more about embedding concepts in different contexts.

Learning Is Contextual Change The knowledge of phenomena that we construct and the intellectual skills that we develop include information about the context in which it was experienced (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Information about the context is part of the knowledge that is constructed by the learner in order to explain or make sense of the phenomenon. The knowledge that is constructed by a learner consists of not only the ideas (content) but also knowledge about the context in which it was acquired, what the learner was doing in that environment, and what the knower intended to get from that environment. That is why abstract rules and laws (such as mathematical formulae), divorced from any context or use, have little meaning for most learners. If learning is embedded in a context, evidence of new learning could result from reusing that knowledge in new contexts.

Learning Is Activity We cannot separate our knowledge of things from our experiences with them. Activity theorists (Leont'ev, 1972) claim that conscious learning and activity (performance) are interactive and interdependent (we cannot act without thinking or think without acting; they are the same). Activity and consciousness are the central mechanisms of learning. The important distinction is that in order to think and learn, it is necessary to act on some entity. Rather than focusing on knowledge states, as cognitive psychologists do, activity theorists focus on the activities in which people are engaged, the nature of the tools they use in those activities, the social and contextual relationships among the collaborators in those activities, the goals and intentions of those activities, and the objects or outcomes of those activities (Jonassen, 2002). Activity theorists readily

accept the contradictions implied by these different theories of learning as a necessary part of an activity system involving many scholars trying to understand learning.

Learning Is Distributed Among the Community As we interact with others in knowledge-building communities, our knowledge and beliefs about the world are influenced by that community and their beliefs and values. So, learning can also be conceived of as changes in our relation to the culture(s) to which we are connected (Duffy & Cunningham, 1996). Through participating in the activities of the community (Lave and Wenger, 1991), we absorb part of the culture that is an integral part of the community, just as the culture is affected by each of its members. Communities of learners, like communities of practitioners, can be seen as a kind of widely distributed memory with each of its members storing a part of the group's total memory. Distributed memory, what the group as a whole knows, is clearly more capacious than individual memories, and so the sharing of those memories makes the community more dynamic.

The group's knowledge is distributed among the participants in these communities (Salomon, 1993). When a complex task has to be performed, members of the group will contribute what they know to the performance of the whole group.

Learning Is Tuning Perceptions to Environmental Affordances Ecological psychologists believe that learning results from the reciprocal perception of affordances from the environment and actions on the environment. That is, different environments afford different kinds of thinking and acting. As learners, we become attuned to what the environment affords us and so we act on the environment in some way. The changes in our abilities to perceive and act on an environment provide evidence of learning. Ecological psychologists emphasize the role of perception in learning.

Learning Is Chaos Ask any middle school teacher. No, what we mean is that learning exhibits characteristics of chaos theory. Learning systems of all sizes tend to behave randomly; that is, we cannot explain the outcomes of the learning systems. When we examine the variables that describe system performance, they do not repeat regularly, so we view the systems as unstable. Learning systems tend not to resist outside disturbances, but rather over-react to changes in conditions. However, in most systems, people do learn. Learning is a self-organizing phenomenon. When people in systems need to learn, they will. As educators, we simply cannot predict it because we are not examining the phenomenon systemically.

So, What Is Learning? It is all of these. Humans are such complex organisms that they are unable to fully understand themselves. That is, we have not yet learned who and what we are. We certainly cannot agree on what it means to

learn. We have briefly described some of the theories that have been constructed to explain what learning is. They all describe some aspects of human learning.

WHAT IS MEANINGFUL LEARNING?

Our assumption in this book is that the primary goal of education at all levels should be to engage students in meaningful learning, which occurs when students are making meaning. While schools play a variety of important social, custodial, and organizational roles in communities, their primary obligation should be to help students to learn how to recognize and solve problems, comprehend new phenomena, construct mental models of those phenomena, and given a new situation, set goals and regulate their own learning (learn how to learn). Figure 1.1 illustrates the interaction of five interdependent attributes of meaningful learning. If we accept that our goal, as technology-using educators, is to support meaningful learning, then we should use technologies to engage students in active, constructive, intentional, authentic, and cooperative learning. These attributes of meaningful learning will be used throughout the book as the goals

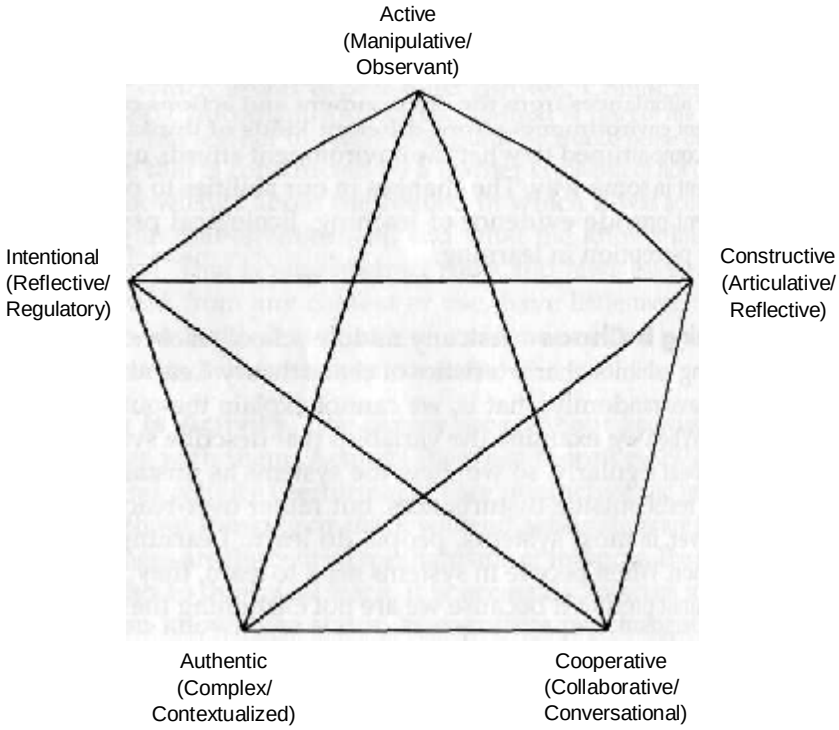

Figure 1.1 Five Attributes of Meaningful Learning

for using technologies as well as the criteria for evaluating the uses of technology. Let's examine these attributes a little more closely.

• **Meaningful Learning Is Active (Manipulative/Observant)** Learning is a natural, adaptive human process. Humans have survived and therefore evolved because they were able to learn about and adapt to their environment. Humans of all ages, without the intervention of formal instruction, can develop sophisticated skills and construct advanced knowledge about the world around them when they need to or want to. When learning about things in natural contexts, humans interact with their environment and manipulate the objects in that environment, observing the effects of their interventions and constructing their own interpreta tions of the phenomena and the results of the manipulation. For instance, before playing sandlot baseball, do kids subject themselves to lectures and multiple-choice examinations about the theory of games, the aerodynamics of orbs, and vector forces of bats? No! They start swinging the bat and chasing fly balls, and they negotiate the rules as they play the game. Through formal and informal apprenticeships in communities of play and work, learners develop skills and knowledge that they then share with other members of those communities with whom they learned and practiced those skills. In all of these situations, learners are actively manipulating the objects and tools of the trade and observing the effects of what they have done. The youngster who consistently hits foul balls will adjust his/her stance and handgrip on the bat continuously in order to manipu late the path of flight and observe the effects of each manipulation. Meaningful learning requires learners who are actively engaged in a meaningful task (not just pressing the spacebar to continue) in which they manipulate objects and parame ters of the environment they are working in and observing the results of their manipulations.

• **Meaningful Learning Is Constructive (Articulative/Reflective)** Activity is necessary but not sufficient for meaningful learning. It is essential that learners articulate what they have accomplished and reflect on their activity and observations—to learn the lessons that their activity has to teach. New experiences often provide a discrepancy between what learners observe and what they understand. They are curious about or puzzled by what they see. That puzzlement is the catalyst for meaning making. By reflecting on the puz-zling experience, learners integrate their new experiences with their prior knowledge about the world, or they establish goals for what they need to learn in order to make sense out of what they observe. Learners begin constructing their own simple mental models to explain their worlds, and with experience, support, and more reflection, their mental models become increasingly complex. Ever more complex models will enable them to reason more consistently and productively about the phenomena they are observing. The active and con-structive parts of the meaning-making process are symbiotic. They both rely on the other for meaning making to occur.

• **Meaningful Learning Is Intentional (Reflective/Regulatory)** All human behavior is goal directed (Schank, 1994). That is, everything that we do is intended

to fulfill some goal. That goal may be simple, such as satiating hunger or getting more comfortable, or it may be more complex, such as developing new career skills or studying for a master's degree. When learners are actively and willfully trying to achieve a cognitive goal, they think and learn more because they are fulfilling an intention. Technologies have traditionally been used to support teacher goals, but not those of learners. Technologies need to engage learners in articulating what their learning goals are in any learning situation and then supporting them. Learners should be required by technology-based learning systems to articulate what they are doing, the decisions they make, the strategies they use, and the answers they found. When learners articulate what they have learned and reflect on the processes and decisions that were entailed by the process, they understand more and are better able to use the knowledge that they have constructed in new situations.

• **Meaningful Learning Is Authentic (Complex/Contextualized)** The greatest intellectual sin that we educators commit is to oversimplify most ideas that we teach in order to make them more easily transmissible to learners. In addition to removing ideas from their natural contexts for teaching, we also strip ideas of their contextual cues and information and distill the ideas to their "simplest" form so that students will more readily learn them. But what are they learning? That knowledge is divorced from reality, and that the world is a reliable and simple place. But the world is not a reliable and simple place, and ideas rely on the contexts they occur in for meaning. At the end of chapters, textbooks re-insert the ideas they presented into some artificial problem for learners to solve in some predictable ways. However, learning often fails because students learned to understand the ideas as algorithmic procedures outside of any context, so they have no idea how to relate the ideas to real-world contexts. Additionally, these textbook problems are constrained, practicing only a limited number of activities that were introduced in the chapter, so when they are faced with complex and ill-structured problems, students do not know where to begin.

Most contemporary research on learning has shown that learning tasks that are situated in some meaningful real-world task or simulated in some case-based or problem-based learning environment are not only better understood, but also are more consistently transferred to new situations. Rather than abstracting ideas in rules that are memorized and then applied to other canned problems, we need to teach knowledge and skills in real-life, useful contexts and provide new and different contexts for learners to practice using those ideas. And we need to engage students in solving complex and ill-structured problems as well as simple, well-structured problems (Jonassen, 1997). Unless learners are required to engage in higher order thinking, they will develop oversimplified views of the world.

• **Meaningful Learning Is Cooperative (Collaborative/Conversational)** Humans naturally work in learning and knowledge-building communities, exploiting each other's skills and appropriating each other's knowledge. In the real world, humans naturally seek out others to help them to solve problems and

perform tasks. Then why do educators insist that learners work independently all of the time? Schools generally believe that learning is an independent process, so learners seldom have the opportunity to "do anything that counts" in collaborative teams despite their natural inclinations. When students collaborate without permission, educators may even accuse them of cheating. However, we believe that relying solely on independent methods of instruction cheat learners out of more natural and productive modes of thinking. Often, educators will promote collaborative methods of learning, only to resort to independent assessment of learning. Learners, they believe, must be accountable for their own knowledge, so even if you agree, at least in principle, with collaborative learning principles, the hardest part of applying your beliefs will be assessing learners. Throughout this book, we will provide vignettes on how groups as well as individuals may be assessed. We cannot forget that most learners are strategic enough to know "what counts" in classrooms, so if they are evaluated individually, collaborative learning activities may fail because students realize that group outcomes are not important.

Collaboration most often requires conversation among participants. Learners working in groups must socially negotiate a common understanding of the task and the methods they will use to accomplish it. That is, given a problem or task, people naturally seek out opinions and ideas from others. Technologies can support this conversational process by connecting learners in the same classroom, across town, or around the world (see chapter 4). When learners become part of knowledge-building communities both in class and outside of school, they learn that there are multiple ways of viewing the world and multiple solutions to most of life's problems. Conversation should be encouraged. In classrooms that focus on individual learning, however, conversation is too often discouraged. In those classrooms, students know that the important views are those espoused by the textbook or the teacher, so conversation is not productive.

As depicted in Figure 1.1, these characteristics of meaningful learning are interrelated, interactive, and interdependent. That is, learning and instructional activities should engage and support combinations of active, constructive, intentional, authentic, and cooperative learning. Why? Because we believe that these characteristics are synergetic. That is, learning activities that represent a combination of these characteristics result in even more meaningful learning than the individual characteristics would in isolation.

There are many kinds of learning activities that engage meaningful learning, just as there are teachers who have for years engaged students in meaningful learning. We argue throughout this book that technologies can and should become the tools of meaningful learning. Technologies afford students the opportunities to engage in meaningful learning if used as learning tools. In the next section, we explicate the assumptions about technologies that underlie their use as learning tools. The remainder of this book describes ways that technologies can be used as tools for learning *with*.

HOW DOES TECHNOLOGY FACILITATE LEARNING?

Learning From *Technology*

Educational technologies have been traced historically to illustrations in 17th-century books and slate chalkboards in 18th-century classrooms. Educational technologies in the 20th century include first lantern-slide projectors, later radio, and then motion pictures. Chapter 5 describes the development of educational television in the 1950s and 1960s. During the same period, programmed instruction emerged as the first true educational technology, that is, the first technology developed specifically to meet educational needs. With every other technology, including computers, educators recognized the importance of each and debated how to apply each nascent commercial technology for educational purposes. Unfortunately, educators have almost always tried to use technologies to teach students in the same ways that teachers had always taught. So information was embedded in the technology (e.g., the content presented by films and TV programs or the teaching sequence in programmed instruction), and the technology presented that information to the students. The students' role was to learn the information presented by the technology, just as they learned information presented by the teacher. The role of the technology was to deliver lessons to students, just as trucks deliver groceries to supermarkets (Clark, 1983). If you deliver groceries, people will eat. If you deliver instruction, students will learn.

The introduction of modern computer technologies in classrooms followed the same pattern of use. Before the advent of microcomputers in the 1980s, mainframe computers were used to deliver drill and practice and simple tutorials for teaching students lessons. When microcomputers began populating classrooms, the natural inclination was to use them in the same way. A 1983 national survey of computer uses showed that drill and practice was the most common use of microcomputers (Becker, 1985).

Later in the 1980s, educators began to perceive the importance of computers as productivity *tools*. The growing popularity of word processing, databases, spreadsheets, graphics programs, and desktop publishing were enabling businesses to become more productive. So students in classroom began word processing and using graphics packages and desktop publishing programs. This tool concept pervaded computer uses according to a 1993 study by Hadley and Sheingold. They showed that well-informed teachers were extensively using text processing tools (word processors), analytic and information tools (especially databases and some spreadsheet use), and graphics tools (paint programs and desktop publishing) along with instructional software (including problem-solving programs along with drill and practice and tutorials).

The development of inexpensive multimedia computers and the eruption of the Internet in the mid-1990s quickly changed the nature of educational computing. Communications and multimedia, little used according to Hadley and Sheingold, have dominated the role of technologies in the classroom ever since. But what are the students producing? Too often, they are using the technology to reproduce what the teacher or textbook told them.

Our conception of educational computing and technology use, described below, does not conceive of technologies as teachers. Rather, we believe that in order to learn, students should be teachers, *representing* what they know rather than memorizing what teachers and textbooks tell them. Technologies provide rich and flexible media for representing what students know and what they are learning. A great deal of research on computers and other technologies has shown that they are no more effective at teaching students than teachers, but if we begin to think about technologies as learning tools that students learn *with,* not *from,* then the nature of student learning will change.

Learning With *Technology*

The ways that we use technologies in schools should change from technology-as-teacher to technology-as-partner in the learning process. Students do not learn from technology, they learn from thinking. Technologies can engage and support thinking when students learn *with* technology. But, how do students learn *with* technologies? How can technologies become intellectual partners with students? If you agree with this role for technologies, then you must make a different set of assumptions about what technologies are and what they do. Throughout this book, we assume that:

- Technology is more than hardware. Technology consists also of the designs and the environments that engage learners. Technology can also consist of any reliable technique or method for engaging learning, such as cognitive learning strategies and critical thinking skills.
- Learning technologies can be any environment or definable set of activi ties that engage learners in active, constructive, intentional, authentic, and cooperative learning.
- Technologies are not conveyors or communicators of meaning, nor should they prescribe and control all learner interactions.
- Technologies support learning when they fulfill a learning need—when interactions with technologies are learner-initiated and learner-controlled, and when interactions with the technologies are conceptually and intel lectually engaging.
- Technologies should function as intellectual tool kits that enable learners to build more meaningful personal interpretations and representations of the world. These tool kits must support the intellectual functions that are required by a course of study.
- Learners and technologies should be intellectual partners, where the cog nitive responsibility for performing is distributed by the part of the part nership that performs it the best.

Traditionally, technologies have been used to teach students. That is, they have been used to deliver and communicate messages to students who, it is hoped, comprehend those messages and learn from them. The underlying assumption is that people learn *from* technology; that is, students learn from watching instructional films and television or responding to programmed

instruction or computer-assisted instruction frames, just the same as they learn from listening to a lecture by the teacher. This view assumes that knowledge can be transmitted from the teacher to the student and that knowledge can be embedded in technology-based lessons and transmitted to the learner. So students learn *from* technology what the technology knows or has been taught, just as they learn from the teacher what the teacher knows.

In this book, we argue that students cannot learn what either teachers or technologies know. Rather, students learn from thinking—thinking about what they are doing or what they did, thinking about what they believe, thinking about what others have done and believe, thinking about the thinking processes they use—just thinking. Thinking mediates learning. Learning results from thinking.

How Technologies Foster Learning

If technology is used to support learning in the ways that we have described, then it will not be used as delivery vehicles. Rather, technologies should be used as engagers and facilitators of thinking and knowledge construction. Some useful roles for technologies in learning include:

- Technology as tools to support knowledge construction:
  - for representing learners' ideas, understandings, and beliefs
  - for producing organized, multimedia knowledge bases by learners
- Technology as information vehicle for exploring knowledge to support learning by constructing:
  - for accessing needed information
  - for comparing perspectives, beliefs, and worldviews
- Technology as context to support learning by doing:
  - for representing and simulating meaningful real-world problems, situ ations, and contexts
  - for representing beliefs, perspectives, arguments, and stories of others
  - for defining a safe, controllable problem space for student thinking
- Technology as social medium to support learning by conversing:
  - for collaborating with others
  - for discussing, arguing, and building consensus among members of a community
  - for supporting discourse among knowledge-building communities
- Technology as an intellectual partner (Jonassen, 2000) to support learning by reflecting:
  - for helping learners to articulate and represent what they know
  - for reflecting on what they have learned and how they came to know it
  - for supporting learners' internal negotiations and meaning making
  - for constructing personal representations of meaning
  - for supporting mindful thinking

As we will argue in chapter 2, technologies should be used to help learners to solve problems. Classroom technologies can best support problem solving by helping learners to access information, model the problems, and make decisions.

Each technology activity described in this book will be examined for the engagement of meaningful learning activities (active, constructive, intentional, authentic, and collaborative) as well as for their roles (accessing information, modeling the problems, and making decisions) in helping learners to solve problems.

IMPLICATIONS OF CONSTRUCTIVISM

Using technologies as constructivist tools assumes that our conceptions of education will change, that schools or classrooms (at least those that use technologies in the ways that we describe) will reform the educational process. Although few people would ever publicly admit that schools should not emphasize meaningful learning, most people in our society tacitly accept that schools do not. Intentional learning presupposes that parents, students, and teachers will realize this and demand more. They will demand change, so that thinking and problem solving (see chapter 2) are valued as much as memorizing. Technologies will not be the cause of the social change that is required for a renaissance in learning, but they can catalyze that change and support it if it comes.

Implications for Teachers

In order for students to learn ***with*** technology, teachers must accept and learn a new model of learning. Traditionally, teachers' primary responsibility and activity have been directly instructing students, where teachers were the purveyors of knowledge and students the recipients. That is, the teacher told the students what they knew and how they interpreted the world according to the curriculum, text-books, and other resources they have studied. Teachers are hired and rewarded for their content expertise. This assumes that the ways in which teachers know the world are correct and should be emulated by the students. Students take notes on what teachers tell them and try to comprehend the world as their teachers do. Successful students develop conceptions more similar to teachers' conceptions. Learners will not be able to learn ***with*** technology in this kind of learning context. They will not be able to construct their own meaning and manage their own learning if teachers do it for them.

So, first and foremost, teachers must relinquish at least some of their authority, especially their intellectual authority. If teachers determine what is important for students to know, how they should know it, and how they should learn it, then students cannot become intentional, constructive learners. They aren't allowed. In those classroom contexts, there is no reason for students to make sense of the world—only to comprehend the teacher's understanding of it. We believe that the students' task should not be to understand the world as the teacher does. Rather, students should construct their own meaning for the world. If they do, then the teachers' roles shift from dispensing knowledge to helping learners construct more viable conceptions of the world. We said earlier that we believe that not all meaning is created equally. So the teacher needs to help students to discover what the larger

community of scholars regards as meaningful conceptions and to evaluate their own beliefs and understandings in terms of those standards. Science teachers should help students comprehend the beliefs of the scientific community. Social studies teachers should examine with their students the values and beliefs that societies have constructed. In this role, the teacher is not the arbiter of knowledge but rather is a coach who helps students to engage in a larger community of scholars.

Teachers must also relinquish some of their authority in their management of learning. They cannot control all of the learning activities in the classroom. If teachers determine not only what is important for students to know, but how they should learn it, then students cannot be self-regulated learners. They aren't allowed.

Finally, teachers must gain some familiarity with the technology. They must gain skills and fluency with the technology. However, they will be most successful in helping students to learn *with* technology if they do not learn about the technologies in order to function as the expert. Rather, they should learn to coach the learning of technology skills. In many instances, teachers will be learning with the students. We have worked in many school situations where the students were constantly pushing our understanding of the technology. Often, we were barely keeping ahead of the students. They can and will learn *with* technologies, with or without the help of the teacher. That does not mean that as a teacher, you can abdicate any responsibility for learning the technologies. Rather, teachers should try not to be the expert all of the time.

These implications are very problematic for many teachers. They require that teachers assume new roles with different beliefs than they have traditionally pursued. Most teachers in most schools will find these implications challenging. We believe that the results will justify the risks. Just as teachers must assume new roles, learning *with* technology requires that students also assume new roles.

Implications for Students

If teachers relinquish authority, learners must assume it. Learners must develop skills in articulating, reflecting on, and evaluating what they know; setting goals for themselves (determining what is important to know) and regulating their activities and effort in order to achieve those goals; and collaborating and conversing with others so that the understanding of all students is enriched. Many students are not ready to assume that much responsibility. They do not want the power to determine their own destiny. It is much easier to allow others to regulate their lives for them. How skilled are students at setting their own agendas and pursuing them? Many students believe in their roles as passive recipients. However, our experience and the experience of virtually every researcher and educator involved with every technology project described in this book show that most students readily accept those responsibilities. When given the opportunity, students of all ages readily experiment with technologies, articulate their own beliefs, and construct, co-construct, and criticize each other's ideas. When learners are allowed to assume ownership of the product, they are diligent and persevering builders of knowledge.

Constructivist approaches to learning, with or without technology, are fraught with risks for students, parents, teachers, and administrators. Change always assumes risks. Many of the activities described in this book entail risks. We encourage you to take those risks. The excitement and enthusiasm generated by students while they construct their own understanding using technology-based tools are more than sufficient rewards for taking those risks.

CONCLUSIONS

An underlying assumption of this book is that the most productive and meaningful uses of technology will not occur if technologies are used in traditional ways— as delivery vehicles for instructional lessons. Technology cannot teach students. Rather, learners should use the technologies to teach themselves and others. Meaningful learning will result when technologies engage learners in:

- knowledge construction, not reproduction
- conversation, not reception
- articulation, not repetition
- collaboration, not competition
- reflection, not prescription.

After chapter 2, the remainder of this book describes how technology-based activities can support meaningful learning in schools from a constructivist perspective. While the focus of the book is K-12, most of the ideas we present are also valid for universities, corporations, and other learning agencies.

THINGS TO THINK ABOUT

If you would like to reflect on the ideas presented in this chapter, consider your responses to the following questions.

1 If learners cannot know what the teacher knows because they do not share a common knowledge and experience base, how can we be certain that students learn important things? For instance, if you want to teach students about the dangers of certain chemical reactions in the lab, how do we ensure that learners know and understand those important lessons?
2 What is your theory of learning? From your perspective, how do people learn?
3 Is it possible to learn (construct personal meaning) without engaging in some activity? That is, is it possible to learn simply by thinking about something? What are you thinking about? Can you think of an example?
4 When learners construct knowledge, what are they building? How is it possible to observe the fruits of their labor, that is, the knowledge they construct?

5 Think back to your childhood. What can you remember from your early childhood? Where did your remembrance occur? What meaning did it have at the time? How has that meaning changed over time?
6 Think about a recent controversial topic that you have heard or read about. What are the different sides arguing about? What do they believe? What assumptions do they make about what is causing the controversy? Where did those beliefs come from?
7 Radical constructivists argue that reality exists only in the mind of the knower. If that is true, is there a physical world that we live in? Prove it.
8 Some educators argue that we learn much more from our failures than from our successes. Why? They believe that we should put students in sit uations where their hypotheses or predictions fail. Can you think of a sit uation in which you learned a lot from a mistake?
9 Recall the last difficult problem that you had to solve. Did you solve it alone, or did you solicit the help of others? What did you learn from solv ing that problem? Can that learning be used again?
10 Can you learn to cook merely from watching cooking shows on televi sion? What meaning do you make from the experiences that you observe? Will the experience that you have when you prepare a dish be the same as that of the television chef? How will it be different?
11 Technology is the application of scientific knowledge, according to many definitions. Can you think of a teaching technology (replicable, proven teaching process) that does not involve machines?
12 Can you calculate the exact square root of 2,570 without a calculator? Does the calculator make you smarter? Is the calculator intelligent?
13 Describe the thinking processes engaged by a short answer vs. a multiple-choice test question. Are the processes different? Are they assessing knowledge? Is that knowledge meaningful? Why or why not?
14 Can you think of an activity that makes you dumber, not smarter? Do you learn anything from that activity?
15 Have you ever produced your own video, movie, slide show, or computer program? How did it make you think? How did it make you feel?

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